NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

October 2, 2000

MATERIALS LABORATORY FACTUAL REPORT — Report No. 00-134

A. ACCIDENT

Place	: Juneau, Alaska
Date	: June 6, 2000
Vehicle	: Marine Vessel Columbia
NTSB No.	: DCA00-M-M030
Investigator	: Tom Roth-Roffy, MS-30

B. COMPONENTS EXAMINED

Subject bolt with 2 washers, exemplar bolt with 2 washers, intentionally arced bolt with 1 washer

C. DETAILS OF THE EXAMINATION

Several bolts, shown in figures 1 to 3, were submitted for examination. The subject bolt and washers, shown in figure 1, were found unattached to a switchboard at the scene of the accident with the washer bonded to the bolt. The exemplar bolt was found attached to a switchboard at the scene and was removed for comparison. The third bolt was intentionally arced by resting the bolt and washer on two copper bus bars 0.5 inches apart, then applying a 240-volt charge to the bars.

The bolts and washers were examined visually and by optical microscopy. The subject bolt was ultrasonically cleaned in soapy water and then reexamined. The bolts and washers were then sectioned longitudinally, polished, and etched with 2 percent nital. The cross-sections were then examined using optical microscopy and scanning electron microscopy (SEM). The cross-section of the subject bolt and washers were also examined using energy dispersive x-ray spectroscopy.

Subject and Exemplar Bolt and Washers

As shown in figure 1, the subject bolt and washers generally appeared dark in color. Some orange-colored areas were observed in the threaded region of the bolt, on the inner surface of the larger (inner) washer, and around the edge of the inner washer. Beaded orange-colored and dark-colored material was observed on the head, on the outer surfaces of both washers, and in the threaded portion of the bolt. Material was observed filling the thread valleys in the bolt, and, within 0.02 to 0.03 inches of the threaded end of the bolt, the

threads were indiscernible. The thread peaks appeared deformed in one area, indicated by arrow "d" in figure 1.

A relatively large, flattened bead, indicated by arrow "b" in figure 4, was observed on the edge of the inner washer. The bolt seemed to rest easily in a position with the flattened surface of the bead positioned downward. In that position, beads on the head of the bolt were aligned vertically. Also in that position, material that accumulated between the thread peaks was greater on the underside of the bolt, consistent with flow under gravitational forces.

The subject bolt was cut transversely about midway along the threads. The head end (including washers) and the threaded end piece were then sectioned longitudinally. The longitudinal cut through the head end intersected the flattened bead, "b". The longitudinal cut through the threaded end piece intersected the deformed peaks indicated by arrow "d" in figure 1. The cross-sections are shown in figures 5 and 6. An orange-colored material mixed with a dark-colored material was observed around most of the edges of the washers and the bolt shaft. An EDS spectrum of the orange-colored material produced a major peak of copper and a minor peak of iron. An EDS spectrum of the dark-colored material produced a major peak of iron and a minor peak of copper.

The cross-section of the head end of the subject bolt and washers is shown in figure 5. The flattened bead, "b", is highlighted in figure 5, and consisted of orange-colored material mixed with a dark-colored material, with the orange-colored material adjacent to the washer. The edge of the washer appears distinct and undeformed at that location. A layer of orange material was also observed between the washers and the bolt shaft, as shown in figure 7 at higher magnification. The dark circular area in the orange region in figure 7 is a void.

The cross-section of the threaded end portion of the subject bolt is shown in figure 6. The thread peaks were missing in location "d", as shown in the highlighted region to the left. Material was also missing from the end of the bolt, as shown in the highlighted region to the right. The layer of orange and dark material was thickest at location "t", and this area is shown at higher magnification in figure 8. The dark region in the middle thread valley is a void. The threads in this region appear relatively intact and undeformed.

As shown in figure 2, the exemplar bolt and washers were generally lighter in color with fewer orange-colored areas. Beaded orange-colored material was present on the outer surface and edge of the larger washer and on the inner surface of the bolt head. Orange-colored material with a flattened appearance was present on the inner surface of the larger washer. The outer edge of the bolt head had a melted appearance around approximately one third of the head.

Dimensions of the subject (before cutting) and exemplar bolt and washers were measured. Both bolts had a thread diameter of 0.370 inches and a thread pitch of 16 threads per inch. The subject bolt was longer, measuring 1.471 inches compared to the 1.456-inch length of the exemplar bolt. The inner washer of the subject bolt was elliptical,

having an outer diameter ranging from 0.939 inches to 1.030 inches. The inner washer for the exemplar bolt measured 1.004 inches to 1.008 inches. Specified dimensions for the bolts and washers are not known.

Intentionally Arced Bolt and Washer

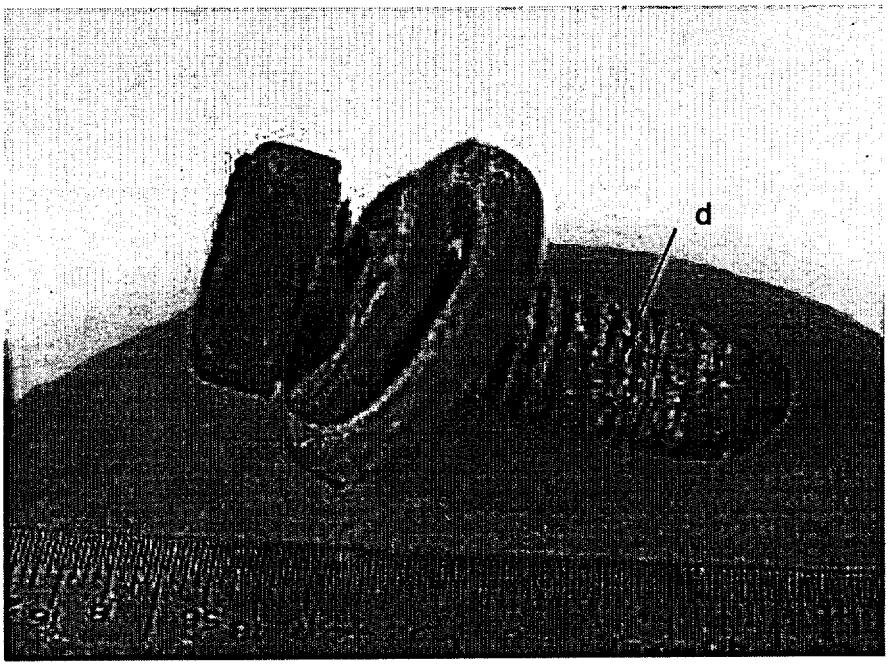
The intentionally arced bolt and washer, shown in figure 3, appeared generally lighter in color than the subject bolt and washers. The head of the bolt appeared partially melted. Two relatively large beaded regions were observed, one in the threaded portion and one at the washer location. The beaded region in the threaded portion appeared porous. The beads appeared mainly dark with some orange color.

The bolt with the washer was sectioned longitudinally in two locations, with one longitudinal cut intersecting the beaded region in the washer and the other intersecting the beaded region in the threaded portion. The cross-sections of the beaded regions in both locations contained orange- and dark-colored material.

A view of the cross-section of the beaded region at the washer location is shown in figure 9. The edge of the washer is missing and appears to have melted into the dark colored phase in the mainly orange-colored bead. A contact region between the washer and bolt was observed, as shown highlighted in figure 9, with no orange-colored material observed between the washer and bolt. Numerous large voids were observed in the orange-colored phase of the beaded material.

A view of the cross-section of the beaded region in the threaded portion of the bolt is shown in figure 10, where the bolt is shown at the top of the figure and the beaded material appears lighter. Thread peaks in this area were missing. Numerous large voids were observed throughout the bead cross-section.

Matthew R. Fox
Materials Engineer



ImageNo:009A0164, Project No:A00064

Figure 1. Overall view of the subject bolt and washers. Arrow "d" indicates location of damaged threads.

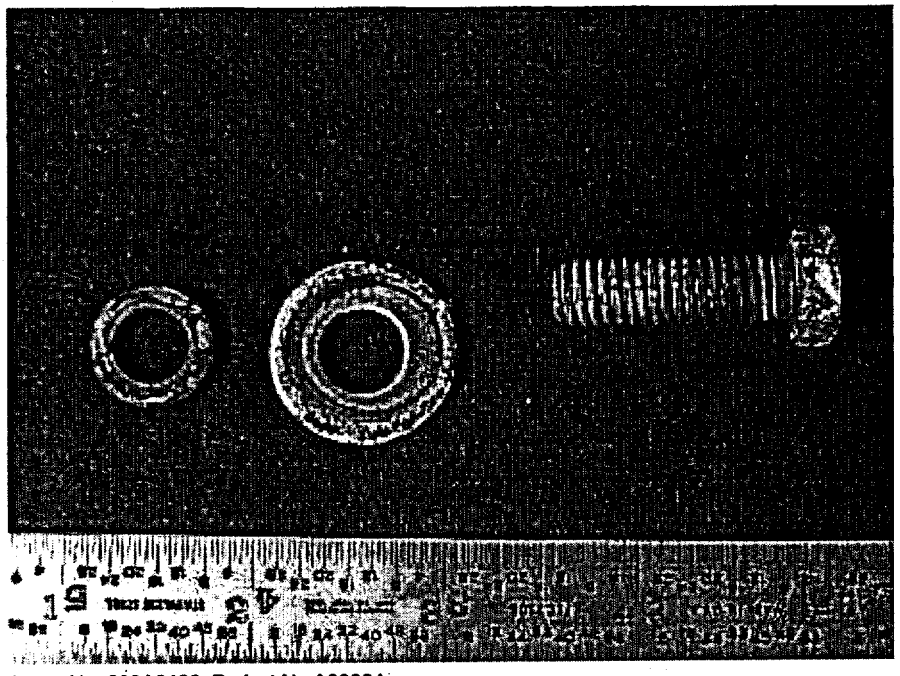


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Figure 2. Overall view of the exemplar bolt and washers.

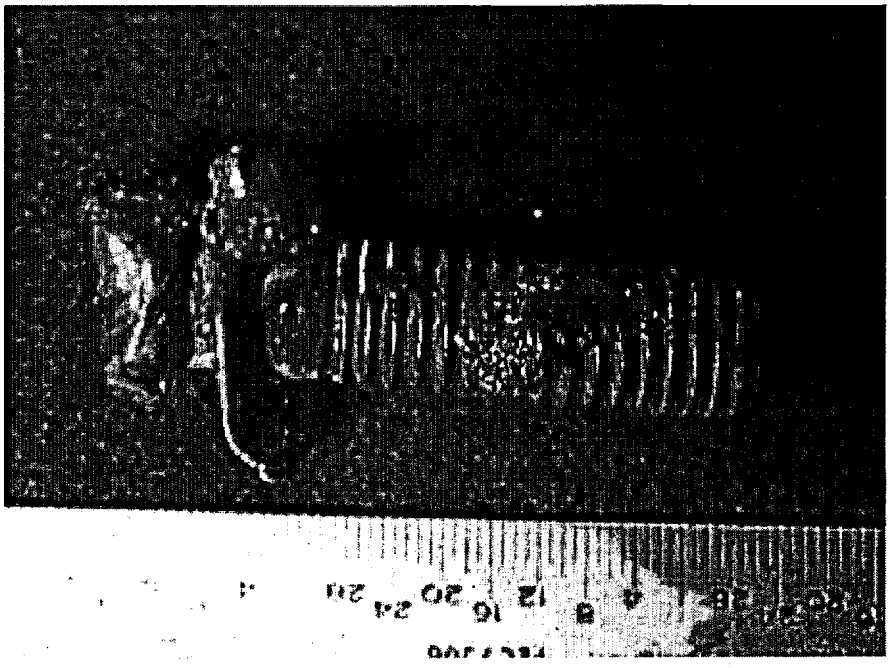

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Figure 3. Overall view of the intentionally-arced bolt and washer.

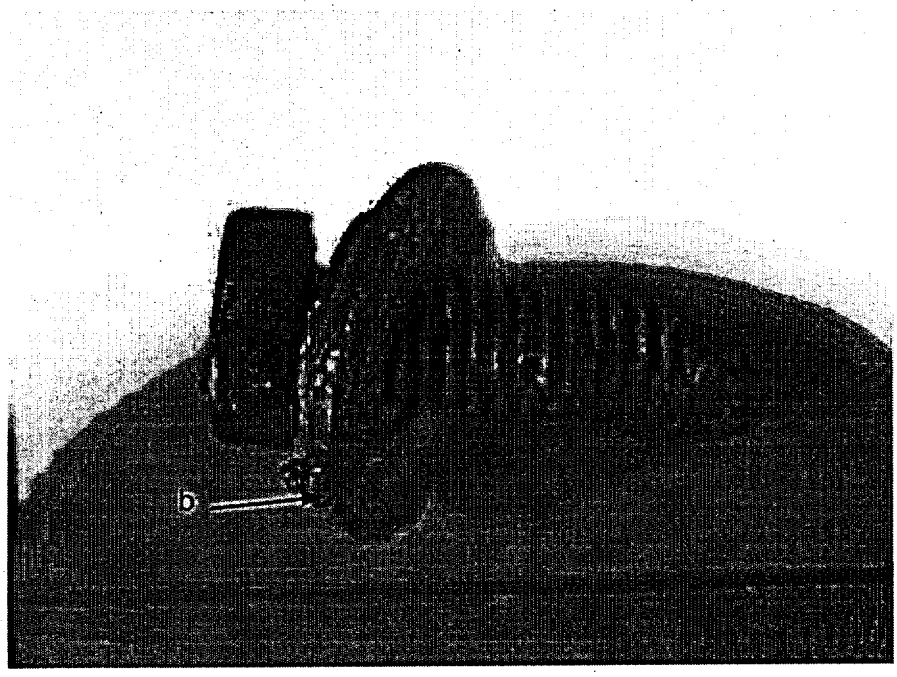

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Figure 4. Another view of the subject bolt and washer. Arrow "b" indicates relatively large bead with flattened surface.

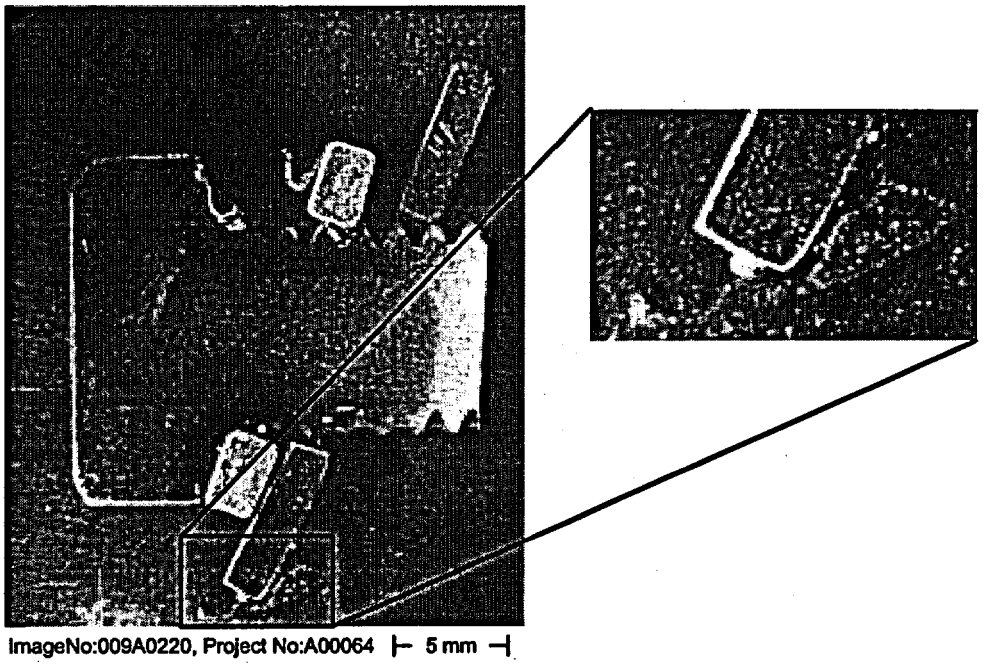


Figure 5. Cross-section of the head portion of the subject bolt. Highlighted region shows the flattened bead at the edge of the washer.

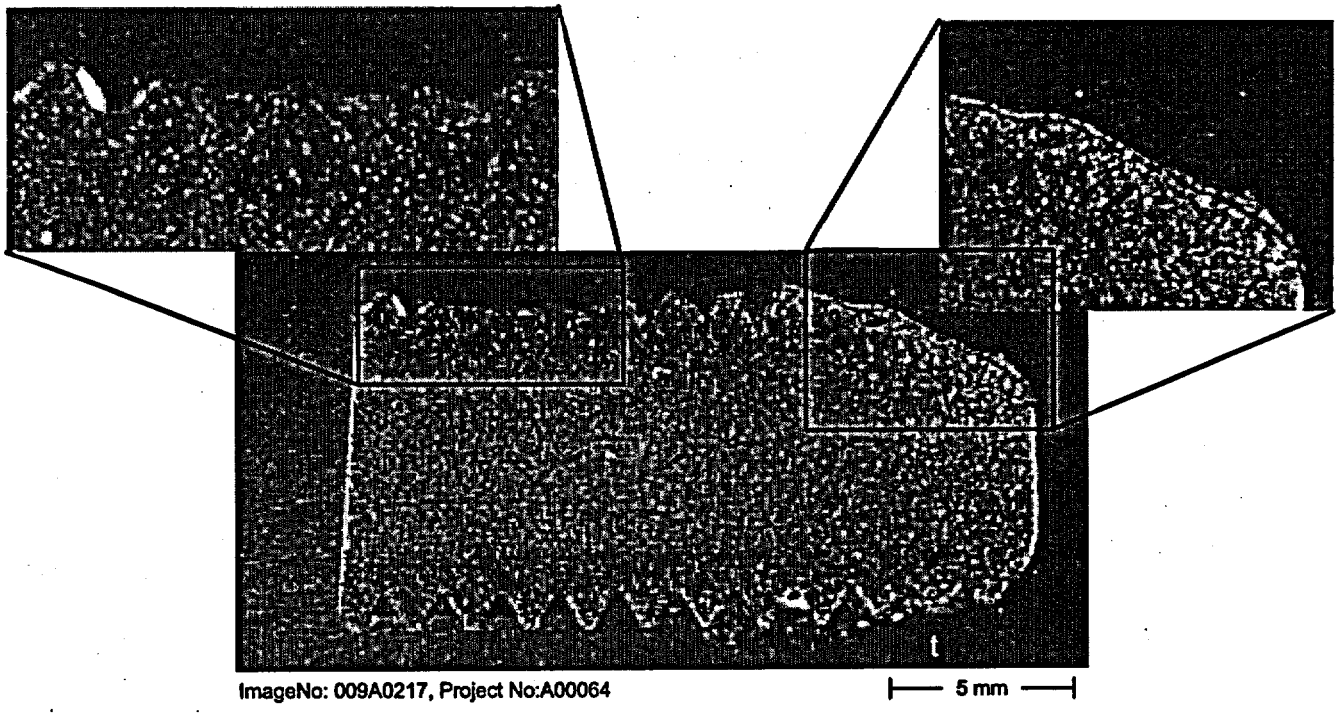
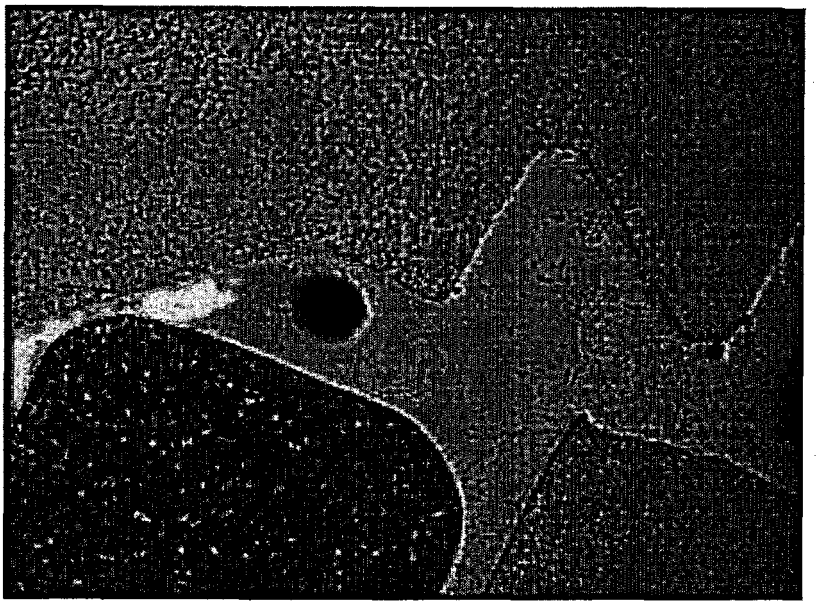


Figure 6. Cross-section of the threaded end piece of the subject bolt. The layer of orange and dark-colored material was thickest at location "t".



ImageNo: 009A0201, Project No:A00064 1 mm

Figure 7. Higher-magnification view of the region between the washers and the shaft in the subject bolt cross-section. The bolt is shown at the top and the washers at the bottom left (outer washer) and right (inner washer). Orange-colored copper fills the region between, with a void appearing as a dark circle in the copper.

ImageNo:009A0213, Project No:A00064 1 mm

Figure 8. Higher magnification view of the material at location "t" from figure 6. The bolt is at the top, and the accumulated material is a mix of copper (orange color) and iron (dark color) phases. A void is present in the middle thread valley.

Figure 9. Cross-section of the intentionally-arced bolt and washer with a highlighted area showing contact between the bolt shaft (above) and washer (below). Orange-colored copper is present on either side of the contact area.

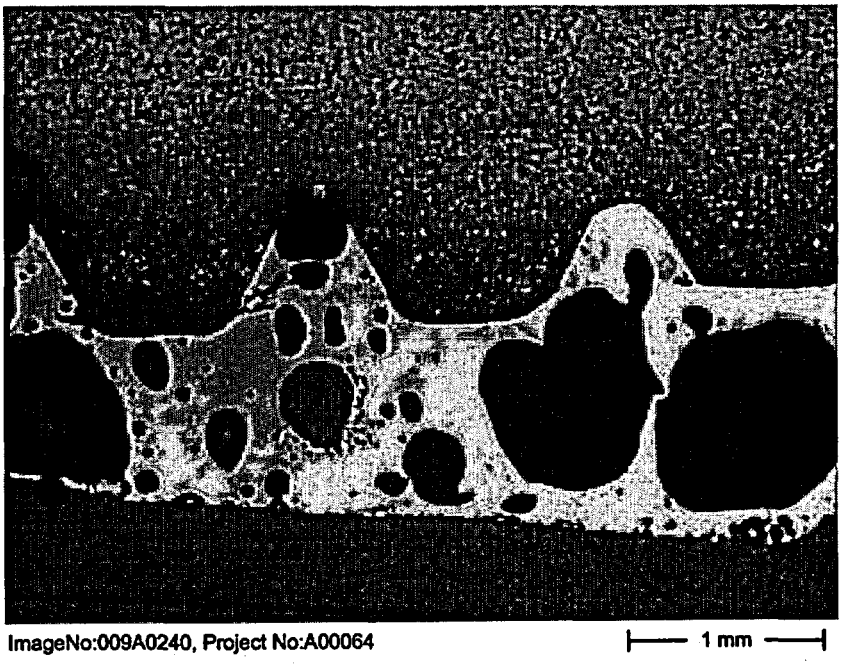


Figure 10. View of the cross-section of the intentionally-arced bolt in the threaded region. The bolt is shown at the top, and the porous copper region appears lighter. The dark areas in the copper region are voids.